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IN THE SUPREME COURT OF THE UNITED STATES

October Term, 1973

No. 73-1092

MRS. WINSTON CALDWELL, Administratrix
and JAMES J. SHANLEY, *Petitioners*

v.

THE UNITED STATES, *Respondent*

PETITION FOR WRIT OF CERTIORARI TO THE UNITED STATES COURT OF CLAIMS

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IN THE SUPREME COURT OF THE UNITED STATES

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JURISDICTION

The Court of Claims judgement, 481 F 2d 898, was entered June 20, 1973. Rehearing was denied by order entered October 17, 1973.

Jurisdiction of this Court to review judgements of the Court of Claims is conferred by Title 28 U. S. Code Section 1255.

QUESTIONS PRESENTED FOR REVIEW

1. *In patent cases, is the inventor in suit?* The Court of Claims placed the inventor in suit. Petitioners contend that patent suits are actions *in rem* and not *in personam;* that the inventor is not in suit; and that the validity of an issued patent is to be determined upon consideration of the patent document rather than interpretation of the inventor's personal qualifications, his experiments, or his scientific theory.

2. *Did the Court of Claims apply the required tests to determine the validity of the patent?* This Court's requirements, set forth in *Graham v. John Deere Co.,* 86 S. Ct. 684, 383 U. S. 1, are: (1) The scope and content of the prior art are to be determined; (2) differences between the prior art and the claims at issue are to be ascertained; and (3) the level of ordinary skill in the art resolved. Petitioners contend that the lower courts are

required to *strictly observe* the stated requirements, as this Court commanded in its decision.

3. *Is 1 to 100 amperes of electrical current substantially the same as 1/1,000,000th ampere of electrical current?* The invention in suit is an electrical generator developed from an electron tube which generates 1 to 100 amperes of electrical current for each square centimeter of electrode surface area. The Court of Claims ruled that the result produced by the invention is *"substantially the same"* as the result produced by the prior art. The Findings of Fact establish that the result produced by the prior art was less than 1/1,000,000th ampere per square centimeter of electrode surface area. Petitioners contend that these results are not substantially the same.

CONSTITUTION AND STATUTES

Constitution Article I, Section 8, Clause 8 delegates to Congress the power:

> To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries;

Title 35 United States Code, Section 103 sets forth the statutory requirement for non-obvious subject matter as a condition for patentability of inventions:

> A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made. (66 Stat. 798)

STATEMENT OF THE CASE

Since 1960 the patented invention has been continously manufactured and used by industrial corporations

acting as contractors to the United States Government. Following unsuccessful licence negotiations, petitioners filed administrative claims with NASA, AEC and other agencies seeking compensation for infringement of their patent by the contractors. The administrative claims were denied in 1970. This suit was then instituted.

The Court of Claims had exclusive original jurisdiction of the case under 28 U.S. Code Section 1498 because the patent infringement occurred under government contracts.

ARGUMENT IN SUPPORT OF WRIT

Petitioners request the Court to review the decision of the Court of Claims and decide whether or not the lower court ruled with the fairness and logic that is expected of a court of the United States. The Opinion, Appendix A, speaks for itself. Petitioners rely on errors which are readily apparent: The Court of Claims improperly placed the inventor in suit; and to the limited extent that it does consider the questions properly before the court, the Opinion disregards the requirements of this Court, and disregards the Findings of Fact. Although this is a patent case, no technical questions are presented. The question is whether the Court of Claims committed *errors of law* which are of sufficient importance to require this Court to exercise its power of supervision over the case.

THE PATENT IS IN SUIT, NOT THE INVENTOR

1. The first error relied upon is the argument that the patent is invalid because no one has yet completely explained the scientific theory of why the invention works. THE DECISION STANDS AS PRECEDENT FOR A NEW CONCEPT THAT INVENTORS ARE TO BE DENIED THEIR PATENT RIGHTS UPON A JUDICIAL INFERENCE THAT THEY DO NOT FULLY UNDERSTAND THE SCIENTIFIC THEORY OF THEIR DISCOVERIES.

The Court of Claims achieves this result through a questionable exercise of judicial innovation. Six pages of the twelve page Opinion are devoted not to the patent, but to "Winston Caldwell, *the inventor in suit* ..." (Opinion p.4).

As a result of the ensuing inquiry into the inventor's qualifications, the Opinion ultimately declares that his experi-

ments, construed together with the contemporary comments of one scientist, "raise the *inference* that he did not fully understand the principles of thermionic emission" (Opinion p. 9).

Petitioners contend that the dialogue is entirely immaterial. However, if the inventor's qualifications are a proper matter for consideration, petitioners would show that the stated inference is incorrect. Respondent's expert testified very candidly that "Caldwell apparently was a *very inventive person*"; and that his experiments were of good quality for *laboratory or graduate level study of thermionic emission.*

2. The correct rule of law which applies to the case is the well-established rule that *a patentee is not required to either know or disclose the scientific theory of his invention.* This is the rule in all United States Courts of Appeals which have considered the question, and was the rule in the Court of Claims until the instant case was decided (Confer *Erie Resistor Corp. v. U. S.,* 150 Ct. Cl. 490, at p. 495 and p. 503). Two columns of case citations to the same effect are noted in 69 CJS Patents Section 53, footnote 98.

THE COURT DID NOT APPLY THE REQUIRED TESTS OF PATENT VALIDITY

3. Petitioners readily admitted throughout trial that the invention uses a scientific principle discovered by Edison in 1884, and the separate elements of the invention are common elements of radio tubes. Respondent's expert testified that no one had previously *combined* these elements in the manner patented. Further, respondent has used the patented combination exclusively, and has not used any of the combinations described in the prior art.

In view of the undisputed facts, petitioners repeatedly asked:

> Would the particular combination and arrangement discovered by Caldwell, which had eluded highly skilled scientists and inventors for seventy years or more, be obvious to a person ordinarily skilled in the electron tube art in 1953 when Caldwell's patent application was filed?

PETITIONERS' QUESTION REMAINS UNANSWERED!!!!

Instead of answering petitioners' direct question, the Opinion adopts the argument that the invention involves "sophisticated scientific principles" and that further research was required to develop a "practical" thermionic converter. This is exactly the same argument that was rejected by this Court in 1888 (*The Telephone Cases*, 126 U.S. 1). Caldwell's invention depends on the particular method and apparatus disclosed in the patent claims, and not upon any new scientific theory. The claims are mentioned in only one brief paragraph of the entire Opinion (Opinion p. 9). Claims 1 and 21, on which petitioners principally rely, are not discussed at all.

4. The Court of Claims failed and refused to apply the three-part test laid down by this Court in *Graham v. John Deere Co., supra.* The Opinion does not consider the *differences* between the known art and the claims in suit. The Opinion discloses no effort to resolve the level of *ordinary* skill in the pertinent art. Instead, the Opinion relies on the writings of highly skilled scientists, each of whom had *failed* to discover the combination patented here.

1/1,000,000TH AMPERE IS NOT 1 TO 100 AMPERES

5. The Court of Claims ruled as a matter of law that the patented combination "functions substantially identically to the prior art *to produce substantially the same result*" (Opinion p. 12). Therefore, the Opinion concludes that the invention is "no more workable" than the prior art devices. This is contrary to the Findings of Fact.

On the record, the invention in suit produces a voltage of about one volt and current ranging from 1 to 100 amperes for each square centimeter of electrode surface area (Opinion p. 4). Higher voltages are obtained by the conventional expedient of connecting the cells in series, like a battery. The Opinion clouds these simple facts by making a major issue of an obscure sentence of the patent disclosure which suggests that voltage might be increased by increasing the size of the device.

The truth is, the only result produced in the prior art is a voltage of "zero volts to 0.365 volts" and current from 0.0874 *microamps* to 0.0039 *microamps*" (Finding 25, p. 29).

To compare results, a "microamp" is one one-millionth part of one ampere of electrical current. Although the volt-

age is about the same, the current, and hence the total electrical power of the Caldwell invention is more than one million times greater than the prior art result.

The Opinion directly contradicts the Findings of Fact. As the Findings of Fact are presumed valid, it follows that the Opinion is in error.

CONCLUSION

The challenged Opinion rides rough shod over the deceased inventor and then declares his patent invalid for reasons that defy law and logic. This case presents an extreme example of the anti-patent attitude that has prevailed in the courts since 1930. Should there not be some limit as to how far the courts may go in striking patents down?

To a nation in the throes of an energy crisis, this Court's 1918 caution would appear sound:

> *"certainly, consideration for the rights of inventors, rather than agression upon them, is a policy of wisdom ... if it, the government, would keep ready for whatever emergency may come to it."* (*United States v. Bethlehem Steel Co.*, 258 U.S. 321, at p. 327.)

Petitioners urge that patents should be judged fairly by the standards laid down by the Court in *Graham, supra,* and its companion cases.

Wherefore, petitioners pray for writ of certiorari to the United States Court of Claims.

Respectfully submitted,

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IN THE UNITED STATES COURT OF CLAIMS

326-70 MRS. WINSTON CALDWELL, ADMINISTRATRIX AND JAMES J. SHANLEY

v.

THE UNITED STATES

Before COWEN, *Chief Judge*, DAVIS, SKELTON, NICHOLS, KASHIWA, KUNZIG and BENNETT, *Judges*.

ORDER

These cases[1] come before the court on motions for rehearing, for new hearing, to vacate the order of the court, for reconsideration, for new trial, for amendment of judgement, for clarification, to reopen case and for further relief under Rules 151 and 152 of the Rules of this court and on consideration thereof,

IT IS ORDERED this 17th day of October, 1973, that said motions be and the same are denied as follows:

326-70 Mrs. Winston Caldwell, Administratrix and James J. Shanley, Plaintiffs' motion for rehearing.

BY THE COURT

/s/ Wilson Cowen
Chief Judge

[1] The Order included twelve unrelated cases.

IN THE SUPREME COURT OF THE UNITED STATES

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No. _____

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PETITION FOR WRIT OF CERTIORARI
TO THE UNITED STATES COURT OF CLAIMS

APPENDIX A

Court of Claims Judgement, June 20, 1973

In the United States Court of Claims

No. 326–70

(Decided June 20, 1973)

MRS. WINSTON CALDWELL, ADMINISTRATRIX, AND JAMES J. SHANLEY v. THE UNITED STATES

French Caldwell, attorney of record, for plaintiffs. *Paul T. O'Neil* and *Shanley & O'Neil*, of counsel.

Michael W. Werth, with whom was *Assistant Attorney General Harlington Wood, Jr.*, for defendant.

Before COWEN, *Chief Judge*, DAVIS, SKELTON, NICHOLS, KASHIWA, KUNZIG, and BENNETT, *Judges*.

OPINION

PER CURIAM: This case comes before the court on plaintiffs' exceptions to a recommended decision filed July 24, 1972, by former Trial Commissioner James F. Davis pursuant to Rule 134(h). The court has considered the case on the briefs and oral argument of counsel. Since the court agrees with the decision, as hereinafter set forth, it hereby affirms and adopts the same as the basis for its judgment in this case. Therefore, plaintiffs are not entitled to recover and plaintiffs' petition is dismissed.

OPINION OF COMMISSIONER

DAVIS, *Commissioner:* This is a patent suit under 28 U.S.C. § 1498. Plaintiffs seek to recover "reasonable and entire compensation" for alleged unauthorized use by defendant, the

United States, of inventions described and claimed in U.S. Patent Re. 24,879 (the '879 patent or the patent in suit), entitled "Method and Apparatus for Converting Heat Directly Into Electricity." The '879 patent was granted to plaintiffs in 1960 on an application filed in 1958 and is a reissue of U.S. Patent 2,759,112 (the '112 patent) granted to the inventor, Winston Caldwell, in 1956 on an application filed in 1953. The '879 patent relates to thermionic converters which are devices for directly converting heat into electricity. There are 25 patent claims. Only claims 1, 2, 16, 17, and 21 are in issue. Claim 1 is a method claim while the others define apparatus. Plaintiffs contend that the claims in issue are infringed by thermionic converter devices supplied to agencies of the United States (NASA, AEC and the military services) by various manufacturers. The accused devices, most of which may be characterized as "cesium thermionic converters," are described in detail in findings 32–38.

Defendant raises the usual issues of patent invalidity and noninfringement. Principal defenses are that the claims are invalid because they define inventions which are "anticipated" under 35 U.S.C. § 102 or "obvious" under 35 U.S.C. § 103, in view of prior art references, most of which were not considered by the Patent Office. Defendant also contends that the patent is invalid under 35 U.S.C. § 112 because it does not "disclose an operative embodiment to carry out * * * [the] invention."[1] Further, defendant says that there is no infringement because the claims, properly construed, do not read on the accused devices; and, in any event, such devices were used by the United States only in "experimental" programs of thermionic converter development and were not used in any practical applications. For reasons discussed below, I hold that the patent claims, construed in light of the disclosure and the prior art, are invalid under 35 U.S.C. § 103. It is therefore unnecessary to consider other issues. *Dow Chem. Co.* v. *Halliburton Oil Well Cementing Co.*,

[1] Section 112. Specification.

The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same, and shall set forth the best mode contemplated by the inventor of carrying out his invention.

324 U.S. 320, 64 USPQ 412 (1945); *Decca Ltd.* v. *United States*, 190 Ct. Cl. 454, 420 F. 2d 1010, 164 USPQ 348 (1970), *cert. denied*, 400 U.S. 865, 167 USPQ 321; *Smith* v. *United States*, 136 Ct. Cl. 487, 145 F. Supp. 396, 111 USPQ 135 (1956).

Background and patent in suit

Thermionic converters are electrical generators which operate on a principle of physics called thermionic emission. When some materials, particularly metals, are heated to high temperatures (*e.g.*, above about 1000° C.), they emit electrons into the surrounding space. This is called thermionic emission. In simplest form, a thermionic converter consists of two closely-spaced electrodes, one called the emitter and the other the collector. The space between electrodes is on the order of 0.01–0.001 inches. The interelectrode space is either highly evacuated (hence a "vacuum thermionic converter") or is filled with cesium vapor at very low pressure, on the order of a few millimeters of mercury (hence a "cesium thermionic converter"). Normal atmospheric pressure is 760 millimeters of mercury. The emitter is heated to a high temperature (about 1000–2000° C.) so as to induce thermionic emission. The collector is maintained at a temperature lower than the emitter (about 600° C.) and captures the emitted electrons, thus creating a potential difference (or voltage) between the emitter and collector. By connecting the collector and emitter through an external circuit, electrical current is made to flow.

Vacuum thermionic converters are inefficient and short-lived. That is to say, the amount of electrical energy generated in relation to heat energy put in is low, on the order of about 5 percent. Cesium thermionic converters are somewhat more efficient, on the order of about 15 percent. There are many reasons for the inefficiency and short life of vacuum thermionic converters, including inherent radiation heat losses from the high-temperature emitter, difficulties of cooling the collector, inefficiencies of electron transfer between emitter and collector, and problems associated with the deterioration of materials of construction. Also, the voltage generated by thermionic converters is limited, among other things, by the temperature difference between electrodes and

the nature of the electrode materials. Generally, the voltage generated is on the order of magnitude of about one volt. The electrical current which can be produced varies considerably with the size, temperature and spacing of the electrodes and is on the order of 1 to 100 amperes per square centimeter of electrode surface area. Typical power ratings of experimental cesium converters procured by the Government were on the order of 50 watts.

Thus it can be seen that there are substantial theoretical and practical problems of making a thermionic converter which will produce quantities of electrical power of the magnitude necessary for useful operations. In fact, the record shows that the Government has spent $50 million on thermionic converter research and development and has yet to come up with a device which is useful for long-term practical generation of electricity. For the most part, the Government's research and development efforts have led only to the conclusion that much more work needs to be done.

Winston Caldwell, the inventor in suit, was an insurance executive and tobacco farmer who, in the late 1940's and early 1950's, did some experimental work on thermionic conversion. Caldwell had a technical education but had little practical experience in physics or electronics. His experiments were carried out in his home, with rudimentary equipment, generally consisting of conventional radio tubes and homemade paraphernalia. The gist of his experiments was to show that a radio tube could function as a thermionic converter by heating one element of the tube (the cathode) to a temperature sufficiently high to induce thermionic emission, in hopes of coming up with a practical thermionic converter. So far as the record shows, his experiments demonstrated nothing more than the principle of thermionic emission, known in the art at least as early as 1884.[2]

In 1953, Caldwell filed a patent application which matured into the '112 patent and, in turn, the reissue '879 patent

[2] In 1954, Caldwell wrote to the Stromberg-Carlson Company, in an attempt to interest it in his ideas on thermionic converters. Stromberg-Carlson replied that it was not interested in pursuing Caldwell's ideas and that "One of our engineers has pointed out that the principle involved [in Caldwell's work] is the well-known 'Edison effect'" described by Edison in 1884. The "Edison effect" demonstrated the principle of thermionic emission. (Finding 23.)

in suit. Caldwell's application stated that his invention relates to an "electron tube designed to convert heat directly into electricity" and was adaptable "to generate and create a high voltage on commercially useful electric current." Among the objects of the invention were "to provide a device * * * which will act efficiently and economically to produce power"; "to provide apparatus * * * which is relatively simple and inexpensive in its construction and installation * * * and which when placed in use will operate efficiently and inexpensively substantially continuously or as desired, without interruption or requirement for repairs or services." Later, during prosecution of the application, Caldwell added as an object to provide "apparatus * * * to utilize large sources of what would otherwise be waste heat, such as heat obtained from solar energy, or from the flue gases from power plants, atomic installations, or blast furnaces, or from the exhaust of jet engines and rocket missiles."

Though all of Caldwell's experimental work leading up to the patent application was performed with commercial radio tubes, the device disclosed in the patent specification is quite different. It comprises, in essence, two concentric cylinders spaced closely together (the specification says "perhaps something like 2/100 of an inch or less"). The space between the cylinders is "exhausted to a high vacuum," the purpose of which is "to prevent injury to the electron emitting coating covering the cathode" and "to create a condition of minimum heat loss from the cathode." The inner cylinder (cathode or emitter) is coated with a "material capable of emitting electrons" (such as thoriated tungsten) and, in one embodiment, is filled with "a large number of lengths of fine gauge refractory insulated wire" which Caldwell's drawings designate an "electron emissive substance." The cathode is to be heated by a burner or other heat source. The outer cylinder (plate or collector) is of unspecified material but is to be maintained, during operation, at a temperature below that of the emitter. Caldwell does not state how such lower temperature is to be maintained or what the temperature difference should be. The specification further states that a "commercially useful apparatus would be made with an overall diameter of 5 feet or more, and will be 10 feet

to 20 feet tall * * *," and that the "voltage will be increased by increasing the size of the apparatus."

Caldwell never built a device as described in the patent specification; and the expert testimony at trial shows that such a device, if built, would not operate as envisioned by Caldwell. (Findings 18 and 19.) In fact, the record establishes that Caldwell's device and concepts were impractical and were based on misconceptions or misunderstandings of the process of thermionic emission. *E.g.*, Caldwell thought that increasing the size of the device would increase the voltage output. Plaintiffs concede that this is wrong. Caldwell also thought that the "fine gauge refractory insulated wire" used to fill the cathode (or emitter) would increase electron flow from emitter to collector. This also is wrong, as established by expert testimony.

Pertinent, as corroborative of expert testimony at trial, is an exchange of letters in 1954 between Caldwell and W. G. Dow, Professor of Electrical Engineering, at the University of Michigan. Caldwell described his invention to Dow thus:

> The tube I am trying to build is a model to demonstrate the fact that you can *increase the emission pressure of the electrons, or voltage, by increasing the size of the cathode and having free electrons within the cathode.* The idea of this construction would be to make an efficient type of thermo electric battery. For a commercial application the cathode would have to be constructed quite large, possibly a foot or more in diameter, and it would be heated by gas or some other source of heat.
>
> You can readily see that the device would depend for its success on the emission of electrons from a heated surface coated with electron emitting material, which effect is quite well known. *It further depends for its effectiveness on having a large diameter cathode and having a large number of free electrons inside the cathode. This is the part which is new and is what I am trying to demonstrate.* [Emphasis supplied.]

Dow responded, in essence, that simply increasing the size of the cathode and the number of electrons inside the cathode would have no effect on voltage or current. Further, Dow said:

> Therefore, all I can say, on the basis of a very considerable experience in the electron tube arts and in what is called "physical electronics" is that your plan is un-

> sound in principle. I do *not* wish you to accept this because I say it; I merely suggest that my saying it makes it worthwhile for you to learn to understand the physics behind the situation a little better. Before you pursue the invention any further, I suggest that you study rather carefully chapters 7, 8, and 9 in my book mentioned above. ["Fundamentals of Engineering Electronics," published by John Wiley & Sons, in 1952.]
>
> I hope I may have been of some help to you. Under the circumstances, we would not, of course, want to try to build a model for you, for the reason that we are completely convinced beforehand that you would only experience a disappointment.

Caldwell's patent application, as filed in 1953, had seven claims, defining the invention in varying degrees of specificity but all directed to "an electron tube designed to convert heat directly into electricity." The application met with considerable resistance in the Patent Office. The examiner rejected all claims as "drawn to an apparatus which is apparently inoperative to carry out the objects of the invention." Further, the examiner solicited "affidavits as to tests on apparatus identified with that disclosed * * * setting forth test data from which the examiner may judge whether or not the device in question is operative, or by a demonstration of a working model before the examiner." As noted earlier, Caldwell had not built, nor did he ever build, a device as described and shown in the patent specification and drawings. Nevertheless, to meet the examiner's rejection, Caldwell built a model which comprised, in essence, a conventional 35Z5 radio tube with a cathode and plate. He demonstrated to the examiner that when the cathode is heated to a high temperature, electrons flow from the cathode to the plate, a demonstration of nothing more than the principle of thermionic emission. The demonstration did not show that the apparatus described in the patent specification would operate as alleged to produce significant quantities of useful power. The examiner apparently was not impressed by the demonstration for he again rejected all claims on grounds of inoperativeness. (Finding 20.)

After some further correspondence between Caldwell's attorney and the patent examiner (including another interview), and after some minor modifications were made to the claims, the examiner (without explanation) withdrew the

rejection on inoperativeness and allowed five claims. At no time were any claims rejected as unpatentable over prior art. The only prior art cited by the examiner was a patent to Hansell (finding 30) which the examiner characterized as being "of interest." In 1956, the application issued as the '112 patent.

In 1958, plaintiffs filed for a reissue of the '112 patent, a principal difference between the '112 patent and the newly filed application being the addition of claims which defined the invention as "a *device* for converting heat directly into electricity" rather than "an *electron tube* designed to convert heat directly into electricity." (Emphasis supplied.) Two new prior art references were cited by the examiner during prosecution of the reissue application, including a U.S. patent to Wick (finding 29), and the claims were rejected as unpatentable thereover. After further prosecution including an interview with the examiner, the reissue application was allowed with the five original patent claims and 20 new claims.[3]

The invalidity defense

Section 112, 35 U.S.C., requires that patent specifications describe inventions "in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains * * * to make and use the same * * *." Implicit in that requirement is that the invention described be operable for the purpose disclosed. *Beidler* v. *United States*, 253 U.S. 447 (1920); *E. I. duPont de Nemours & Co.* v. *Union Carbide Corp.*, 250 F. Supp. 816 (N.D. Ill. 1966); *H. C. Baxter & Bro.* v. *The Great Atlantic & Pacific Tea Co.*, 236 F. Supp. 601, 144 USPQ 74 (D. Me. 1964), *aff'd*, 352 F. 2d 87 (1st Cir. 1965), *cert. denied*, 384 U.S. 905 (1966); 2 WALKER, PATENTS §§ 92, 95 (Deller's 2d ed. 1964). While it is not necessary that the disclosure be of an ultimate commercial embodiment, it must at least be sufficient to teach those skilled in the art how to practice the invention without undue experimentation, especially where the invention is in an art involving sophisticated scientific principles. *In re Perrigo*, 48 F. 2d 965, 9 USPQ 152 (CCPA 1931).

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[3] Claims 1, 2, 16, and 17, here in issue, are new to the reissue patent. Claim 21 was claim 1 in the original patent.

Defendant says that Caldwell's patent specification fails to disclose an "operable" invention because the device described therein has never been built and, if built, would not be practical and would not meet Caldwell's stated objectives. Accordingly, says defendant, Caldwell's disclosure does not support the patent claims. That argument is appealing in view of credible expert testimony that Caldwell's device would be "impractical" and would not produce electrical power as intended by Caldwell. It is appealing also because Caldwell's disclosure, construed in light of contemporaneous statements by Caldwell regarding the gist of his invention, is riddled with inaccuracies which raise the inference that he did not fully understand the principles of thermionic emission, nor the practical problems associated with building a workable device. However, on this record, it cannot be said as a matter of law that the Caldwell device is totally inoperative and useless. Defendant's expert conceded that a device built in accordance with Caldwell's teachings might "operate [as a vacuum thermionic converter] with efficiencies on the order of 1 percent." However, there is no doubt that the device could not be made to generate high voltages, nor could it be made to produce power economically and efficiently. Caldwell's patent claims must, therefore, be construed narrowly as defining a "paper" invention and not one which represents a basic or pioneer advance in the art. *International Glass Co.* v. *United States*, 187 Ct. Cl. 376, 408 F. 2d 395, 161 USPQ 116 (1969).

In light of the above, we turn to analysis of the patent claims in view of the prior art. Claim 16 is representative (finding 17) and defines the invention in terms of the elements comprising Caldwell's device. In essence, the claim calls for a cathode (or emitter) having a surface of electron-emissive material, a plate (or collector) mounted in "closely spaced" relation to the emitter, a "vacuum" between the cathode and plate, means to heat the cathode, means to cool the plate, and electrical connections between the cathode and plate. For purposes here material, claims 2, 17 and 21 are substantially the same as claim 16. Claim 1 is to a method and, in essence, defines the steps of operating the device defined in claims 2, 16, 17 and 21. Defendant says the claims

are invalid under 35 U.S.C. § 103 as defining an invention which would have been "obvious at the time the invention was made to a person having ordinary skill in the art," within the meaning of the statute. *Graham* v. *John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966).

At trial, defendant introduced prior art not cited or considered by the Patent Office. As will be seen, the prior art is highly pertinent and overcomes the presumption of validity accorded patents under 35 U.S.C. § 282. *Ellicott Mach. Corp.* v. *United States*, 186 Ct. Cl. 655, 405 F. 2d 1385, 160 USPQ 753 (1969); *International Glass Co., supra.* The prior art is described in detail in findings 22–31 and is here summarized to the extent pertinent. As earlier noted, Thomas Edison demonstrated the principle of thermionic emission in 1884; and plaintiffs do not dispute that thermionic emission was well-known before Caldwell. Though Edison's work was not expressly directed to producing electric power by thermionic emission (finding 23), the fact remains that he taught that heated metal cathodes emit electrons proportionate to the temperature of the cathode, a teaching pivotal to the idea of generating electricity by thermionic emission and of great significance to later investigations. In 1915, Comstock disclosed a device for generating electricity by thermionic emission. (Finding 24.) Comstock recognized that thermionic emission was a mechanism for converting heat into electricity and his work was directed to that end. Comstock's thermionic generator comprised an emitter made of or coated with an electron-emissive material and heated to "red or white heat," and a collector cooled by a water jacket. The emitter and collector were not closely-spaced but rather were out of direct line of one another so as to minimize heating the collector by radiation from the emitter. Comstock's device was no doubt inefficient and impractical for generating any significant electric current, but it shows an early recognition in the art that thermionic converters must have an electron-emissive emitter, heated to red or white heat, a cooled collector and a vacuum chamber.

Also in 1915, Schlichter did experimental work on vacuum thermionic conversion. (Finding 25.) Schlichter's device was

similar to Comstock's except that the electrodes were closely-spaced (about 0.20 inches). Schlichter further recognized that an emitter coated with metal oxide would increase electron emission. Schlichter summed up his work by noting that "thermionic cells are feasible" but operate "uneconomically" because of radiation heat losses.

In 1923, Langmuir did considerable work investigating the nature of thermionic currents, in an attempt to study the effects of electron "space charge" on thermionic emission. (Finding 27.) "Space charge" is created by the presence of electrons around the emitter during thermionic emission. (Finding 8.) Langmuir found that "space charge" impedes the flow of electrons away from the emitter. Then in 1951, Champeix taught that thermionic converters must have, among other things, closely-spaced electrodes in order to minimize the adverse effects of "space charge." Champeix therefore postulated a vacuum thermionic converter with an oxide-coated emitter and a cooled collector, the emitter and collector being very closely-spaced. (Finding 28.)

In sum, by 1951 it was known in the art that thermionic conversion was a means of generating electrical current; that two electrodes were needed, a hot emitter (perhaps coated with an electron-emissive material) and a cool collector; that the electrodes should be closely-spaced; and that the space between electrodes should be evacuated. What remained to be done (and still remains to be done) to build an efficient and practical device is intensive research on materials of construction, as well as further theoretical study on the mechanisms of thermionic emission and electron flow.

Plaintiffs make much of the fact that the prior art does not expressly teach electrode spacing of 0.02 inches or less, which is the spacing disclosed (but not claimed) by Caldwell. Schlichter, in 1915, taught electrode spacing of about 0.20 inches. Langmuir's work on "space charge" effects in 1923 suggests that electrodes must be closely-spaced in order to get significant current flow. Champeix, in 1951, recognizing the "space charge" problem, taught that the electrodes should be very closely-spaced. In view of such teachings, it seems obvious that one would desire to place the electrodes as close

together as possible without actually touching. In any event, it appears that Caldwell's teaching of 0.02 inches electrode spacing is based on the fact that the 35Z5 radio tube, with which he did experimental work, had electrode spacing of 0.015 inches. In early correspondence with his patent attorney, Caldwell suggested a spacing of 0.015 inches, but later (for unexplained reasons) changed to 0.02 inches. Caldwell's disclosure of electrode spacing therefore came from the prior art of radio tubes, and was not based upon any independent finding by Caldwell that such spacing was significant to thermionic conversion. Caldwell taught nothing more than was clearly suggested by the prior art.

In light of the prior art, Caldwell's patent claims cannot stand. The claims define nothing more than a combination of elements old and obvious to those skilled in the art at the time the invention was made, which combination functions substantially identically to the prior art to produce substantially the same result. Caldwell's disclosure added nothing to the art of thermionic conversion to help solve the baffling technological problems of building a practical thermionic converter. At best, Caldwell's disclosure was an invitation to experiment. *The Incandescent Lamp Patent*, 159 U.S. 465 (1895); *Metals Recovery Co.* v. *Anaconda Copper Mining Co.*, 31 F. 2d 100 (9th Cir. 1929); *H. C. Baxter & Bro., supra.*

Finally, plaintiffs would dismiss the prior art as not showing "one single workable thermionic converter." The short answer to this is that plaintiffs have not shown that Caldwell's device is any more "workable" than devices taught or suggested by the prior art. In fact, to date and despite extensive research efforts, no one has come up with a practical thermionic converter which meets Caldwell's objectives. If and when someone does, it will not be the result of any novel or unobvious teachings of Caldwell.[4]

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[4] The record shows that in the 1960's, progress was made in the art of thermionic conversion by, among other things, introducing cesium vapor into the interelectrode space, rather than maintaining the space a vacuum; and most of the Government's research efforts have been along the lines of cesium, rather than vacuum, thermionic converters. (Findings 32–38.) Caldwell does not teach, suggest or claim cesium thermionic converters; and while it is unnecessary to develop the point, there is considerable doubt whether cesium thermionic converters infringe the patent claims, even if valid.

Findings of Fact

1. This is a patent suit under 28 U.S.C. § 1498. Plaintiffs seek reasonable and entire compensation for unauthorized use by and manufacture for defendant, the United States, of the invention disclosed and claimed in U.S. Patent Re. 24,879 (hereafter the '879 patent), entitled "Method and Apparatus for Converting Heat Directly Into Electricity," issued to plaintiffs September 27, 1960, on an application filed August 13, 1958. The '879 patent is a reissue of U.S. Patent 2,759,112 (hereafter the '112 patent) which issued August 14, 1956, on an application filed August 24, 1953, by the inventor, Winston Caldwell. Plaintiffs' petition was filed September 28, 1970.

2. Plaintiff, Mrs. Winston Caldwell, is the widow and administratrix of Winston Caldwell. She holds a 75-percent undivided interest in the '879 patent. Plaintiff, James J. Shanley, a patent attorney, holds a 25-percent undivided interest in the patent on assignment from Winston Caldwell.

3. By stipulation filed November 29, 1971, the parties agreed that trial would be limited to a consideration only of claims 1, 2, 16, 17, and 21 of the '879 patent. Accordingly, the issues before the court are validity of such claims under 35 U.S.C. §§ 102, 103 and 112, and infringement. By further agreement of the parties, accounting issues, if any, are deferred until resolution of the liability issues.

BACKGROUND

4. The '879 patent relates to a device, commonly referred to as a "thermionic converter," for directly converting heat into electricity. The device depends upon a phenomenon called "thermionic emission" by which certain materials, particularly metals, emit electrons into the surrounding space when sufficiently heated. Thermionic emission was known in the art before the Caldwell invention in suit.

5. Two types of thermionic converters are at issue in this case: "vacuum" converters and "cesium" converters. In simplest form, a vacuum thermionic converter consists of two closely-spaced, confronting electrodes with the region between electrodes highly evacuated. A cesium converter is

similar, except that the interelectrode region is highly evacuated and then filled with cesium vapor at a pressure of a few millimeters of mercury. (Normal atmospheric pressure at sea level is 760 millimeters of mercury.) If one of the electrodes (the "emitter" or "cathode") is heated sufficiently, thermionic emission occurs and electrons are "boiled off" its surface into the surrounding space. If the second electrode (the "collector" or "anode") is maintained at a cooler temperature than the emitter, some of the emitted electrons will strike and be captured by the collector. By this process, a voltage potential is created between collector and emitter. If leads are connected between the collector and emitter through an external electrical load, an electrical current will flow through the load.

6. The underlying theory of operation of thermionic converters can be briefly summarized as follows: A certain amount of energy is required to remove an electron from the surface of a solid material, depending on the type of material. This energy is known as the "work function" of the material, and is expressed in units of electron-volts. Conversely, if a free electron is captured by a solid material, its energy is reduced by an amount equal to the work function of the material. In a thermionic converter, energy is supplied to the emitter in the form of heat and some of its electrons acquire a greater energy than the emitter work function and escape into the surrounding space. If the electrons strike the collector, their energy is reduced by an amount equal to the collector work function, which energy appears as heat at the collector. The remaining electron energy is the difference between collector and emitter work functions, and is the maximum output voltage available for driving current through an external load.

7. The theoretical maximum amount of thermionic current per unit area of emitter surface is determined by the so-called Richardson equation, and is proportional to the emitter temperature squared and inversely related to the exponential of emitter work function. Thus, the higher the temperature at which the emitter is operated, the greater the thermionic current and output power; while the greater the emitter work function, the lower the thermionic current.

8. Thermionic emission from a hot emitter into a vacuum

produces a cloud of negatively-charged electrons in the vicinity of the emitter known as "space charge." Space charge inhibits the flow of electrons from emitter to collector, and thus limits the amount of current below that predicted by the Richardson equation. (See finding 27.) In vacuum converters, the adverse effects of space charge may be reduced by having extremely close spacing between electrodes, on the order of 0.001 inches or less. Nevertheless, even with such close interelectrode spacing, the efficiency of these devices (*i.e.*, the ratio of electrical output power to heat input power) is low, on the order of 5 percent or less. Furthermore, close interelectrode spacing, coupled with the necessity of heating the emitter to as high a temperature as possible to maximize thermionic emission, limits the useful life of vacuum converters.

9. Cesium thermionic converters, which were developed after the Caldwell invention, are a significant improvement over vacuum converters. Introducing cesium vapor into the interelectrode region serves three purposes. First, some of the cesium atoms in the interelectrode space become positively ionized either by prior contact with the hot emitter surface or by bombardment from electrons passing from emitter to collector. These positive ions combine with negatively-charged electrons in the space-charge cloud, thereby significantly neutralizing the space charge. Second, a *partial* layer (as opposed to a *complete* layer) of cesium atoms is formed on the emitter surface which reduces its work function. For example, bare tungsten has a work function of 4.52 electron-volts, while tungsten *partially* covered with a layer of cesium would have a work function on the order of three electron-volts. Consequently, the emitter releases more electrons at a given temperature, thereby increasing output current and power. (See finding 6.) Third, a *complete* layer (as opposed to a *partial* layer) of cesium atoms is formed on the relatively cool collector surface which reduces its work function below the emitter work function. For example, a surface completely covered with cesium has a work function approximately equal to the 1.81 electron-volt work function of cesium. Since the output voltage of a thermionic converter is directly related to the *difference*

in work function between emitter and collector, a higher output voltage results because, even though the work function of both emitter and collector are reduced, the work function of the *partially* covered emitter is reduced less than the work function of the *completely* covered collector.

Because the space charge in cesium converters is neutralized by the cesium ions, the interelectrode spacing in cesium converters can be increased without adversely affecting performance. For example, present-day cesium converters have an interelectrode spacing of approximately 0.01 inches, or 10 times the spacing of vacuum converters. As a result of these effects, the efficiency of cesium converters is generally between 10 percent and 20 percent.

10. All thermionic converters must operate at a high enough emitter temperature for thermionic emission of electrons and at low enough collector temperature to preclude substantial back-thermionic emission. These temperatures depend upon the type of emitter and collector materials used. For example, with cesium converters having refractory metal emitters, such as tungsten, the range of emitter temperatures is approximately 1200–3000° C., and the range of collector temperatures is approximately 500–1000° C. Vacuum thermionic converters having refractory metal emitters operate at high emitter temperatures, such as 2000° C. and above. Vacuum thermionic converters having oxide coated emitters operate at emitter temperatures lower than converters having refractory metal emitters. For example, a converter having the emitter coated with strontium-calcium-oxide may operate in a range 950–1150° C.

11. The parties have agreed by stipulation filed November 29, 1971, that thermionic converters differ from conventional vacuum tubes in the following respects:

* * * * *

15. * * *

(4) The function of thermionic emission in electron tubes other than thermionic converters is to provide sufficient electrons at the cathode surface to convey the electric currents imposed on the cathode during tube operation. This function is described in Langmuir U.S. Patent 1,244,217 in the following manner: "Care must be exercised to have the cathode at a high enough tem-

perature *with reference to the current transmitted* so that the vicinity of the cathode is surrounded by free electrons. In other words, the electron emission should be greater than necessary to convey the current thereby preventing a removal of the active thorium material on the surface of the cathode by a bombardment of positive ions." From this it is clear that the function of thermionic emission in the general electron tube art is distinguishable from the function of thermionic emission in thermionic conversion devices. In thermionic conversion thermionic emission serves as the prime source of electric currents.

(5) In all thermionic converters known to the plaintiffs, including those made and used by or for the defendant, the emitters are operated at significantly higher emitter temperature than the temperatures utilized for coated emitters in the prior electron tube art. Kingdon and Langmuir U.S. Patent 1,648,312 teaches the use of cesium-coated emitters at temperatures in the range 700° K to 1000° K [427–727° C.]. Some cesium thermionic converter emitters are operated in the temperature range 1500° K [1227° C.] to 1800° K [1527° C.] or higher, which is the range from bright red heat to white heat.

16. * * *

(1) Thermionic converters function as prime generators of electricity and to convert heat [sic] to electricity rather than control the flow of impressed electric currents.

(2) Thermionic converters require confronting spaced electrodes of substantially corresponding area, with relatively large electrode surfaces. (For practical power, converters interconnected in series relation to obtain voltage addition.)

(3) Thermionic converters require emitters operating at relatively high emitter temperatures.

(4) Thermionic converters require that the collector be kept substantially cool relative to the high temperature of the spaced emitter.

* * * * *

PATENT IN SUIT

12. (a) The '879 patent (as well as the original '112 patent) discloses a vacuum thermionic converter that, as stated in the specification, "can be used to generate and create a high voltage on commercially useful electric current." The construction and operation of the device can best be under-

stood with reference to patent Fig. 1, reproduced below, which shows a cross-sectional view of the preferred embodiment of the invention.

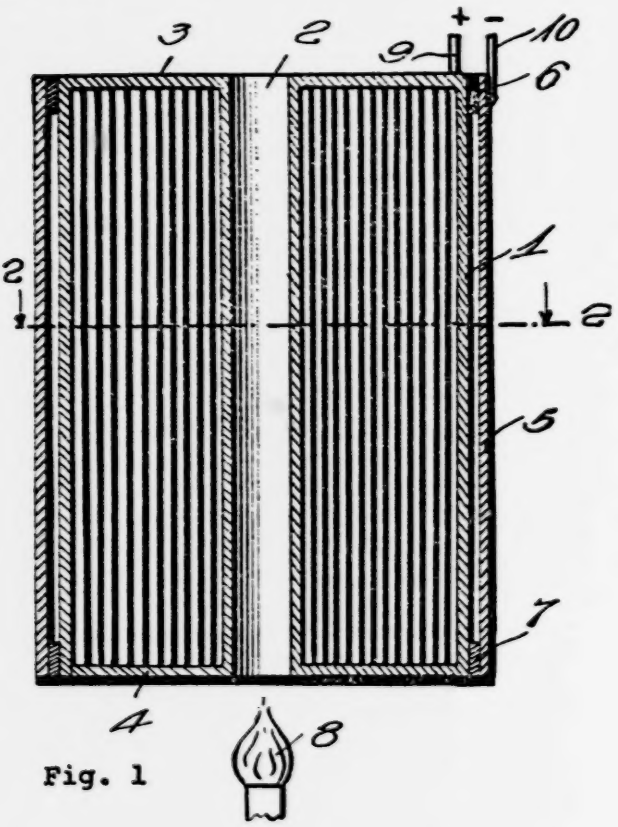

Fig. 1

The cathode (or emitter) consists of a cylindrical side wall 1 and a cylindrical central core or flue 2 which are connected together and closed at their ends by annular top plate 3 and bottom plate 4. The anode (or collector) is a metal cylinder 5 concentric with and in close proximity to the exterior portion of cathode side wall 1. Anode 5 is electrically insulated from cathode wall 1 by end rings 6 and 7. The region between anode 5 and cathode wall 1 is exhausted to a "high vacuum."

The specification further states that a "commercially useful" apparatus would be 5 feet or more in diameter, 10 to 20 feet tall, and would have an interelectrode spacing that is "quite small, perhaps something like 2/100 of an inch or less."

(b) In one embodiment of the invention, the interior cathode space between flue 2 and wall 1 is evacuated to "slightly less than a high vacuum" and filled with a large number of lengths of fine gauge refractory insulated wire, shown more clearly in patent Fig. 2, reproduced below.

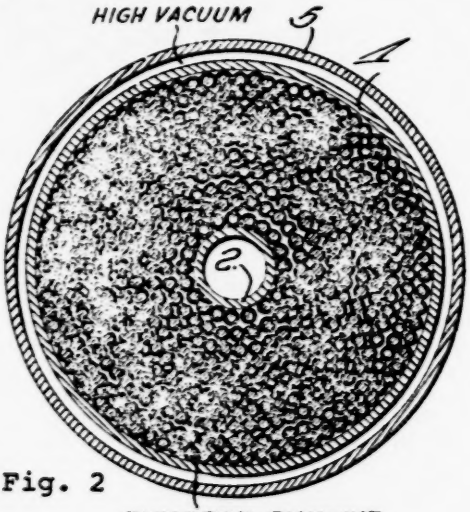

Fig. 2

The specification states that the "efficiency" of the device may be increased by coating these wires with an electron-emitting material, such as barium-calcium-strontium oxide: filling the interior of the cathode with an inert gas; and coating the outer surface of cathode wall 1 with an electron-emitting material, or, alternatively, making the cathode of thoriated tungsten.

13. In operation, the cathode is heated to "red heat or better" by a heat source, such as burner 8, while anode 5 is maintained "relatively cool." However, no means are disclosed for cooling the anode. By the process of thermionic emission, electrons flow from cathode to anode to create a

potential difference. An electron current then flows to an external load through external lead 10, and returns to the cathode through external lead 9. The specification states that "the voltage will be increased by increasing the size of the apparatus."

14. In an alternative embodiment (patent Fig. 3, not reproduced here), a plurality of metal disks or rings are positioned in the interior of the cathode to produce uniform heat transfer from the heating core. The specification says that the "interior of the cathode * * * [is] filled with gas or vapor or other suitable medium or material." The disks have openings to permit the flow of gas within the emitter.

15. Neither of the embodiments disclosed in the '879 patent (findings 12(b) and 14) was ever constructed. All of Winston Caldwell's thermionic converter experiments, both prior to and subsequent to the filing of the '112 and '879 applications, were conducted with commercially-available diode vacuum tubes.

16. The stated objects of the '879 patent include the following:

> An object of my invention is to provide a device * * * which is simple in construction and operation and which will act efficiently and economically to produce useable power.
>
> Another object is to provide apparatus * * * which is relatively simple and inexpensive in its construction and installation; and which can be installed and used for a variety of uses and power requirements or purposes; and which when placed in use will operate efficiently and inexpensively substantially continuously or as desired, without interruption or requirement for repairs or services.
>
> A further object is the provision of apparatus * * * to utilize large sources of what would otherwise be waste heat, such as heat obtained from solar energy, or from the flue gases of power plants, atomic installations or blast furnaces, or from the exhaust of jet engines and rocket missiles. In the case of waste heat from jet engines and rocket missiles, such apparatus can be used to operate the electrical equipment of the device.

17. Claims 1, 2, 16, 17, and 21, the claims in issue, are set out below in outline form for ease of understanding:

> 1. Method of converting heat directly into electricity by a device including a cathode having a surface

including electron emissive material closely spaced from the surface of a plate having an area substantially corresponding to the area of the surface including electron emissive material, which method comprises the steps of

heating the cathode to a temperature higher than the electron emissive temperature of the electron emissive material,

maintaining the plate at a low temperature relative to the temperature of the cathode when heated to the high temperature to enhance the flow to the plate of electrons emitted from the electron emissive surface of the cathode,

connecting power lines to the cathode and to the plate to develop a potential across the power lines as a function of the electrons collected by the plate, and

establishing the area of the electron emissive surface of the cathode and heating the cathode to a predetermined high temperature to develop and maintain a desired potential across the power lines.

2. A device for converting heat directly into electricity, comprising

a cathode and a plate,

means for mounting the cathode relative to the plate with a portion of the cathode confronting and closely spaced from a portion of the plate,

the last-named means including sealing means joined to the cathode and the plate in sealing relationship with the cathode and the plate and electrically insulating the cathode and the plate from each other,

the sealing means and the cathode and the plate hermetically enclosing the space between the closely spaced portions of the cathode and the plate,

the closely spaced portion of the cathode including electron emissive material,

electrical connections from the cathode and the plate, and

heating means for the cathode outside of the space between the closely spaced portions of the cathode and the plate.

16. A device for converting heat directly into electricity comprising

a plate structure and

a cathode structure,

the cathode structure including a surface of extensive area of electron emissive material,

means for mounting the cathode structure and the plate structure in assembled relationship with a surface of the plate structure of extensive area confronting and being in closely spaced relation with the surface of electron emissive material of the cathode structure,
the plate structure and the cathode structure being insulated one from the other and having a vacuum therebetween,
means to contact the cathode structure with a hot fluid to heat the cathode structure,
means to remove heat from the plate structure, and
electrical connections from the cathode structure and the plate structure.

Claim 17 is identical to claim 16, except that it further states that the areas of the "confronting surfaces" are "substantially equal."

21. An electron tube designed to convert heat directly into electricity comprising
a cathode structure coated with material emitting electrons when heated,
an enclosing plate structure,
the coating on said cathode structure facing said plate structure,
said cathode and enclosing plate structure being closely spaced and being insulated one from the other and having a vacuum therebetween,
means to heat said cathode structure, and
electrical connections from said cathode structure and said plate structure.

18. The '879 specification does not describe how the thermionic converter efficiency is increased by filling the interior of the cathode with (i) inert gas and (ii) wires coated with an electron-emitting material. However, correspondence a few months prior to the filing of the original '112 application from Winston Caldwell to Lloyd W. Patch, the patent attorney who prosecuted the '112 and '879 applications, reveals that Caldwell believed these wires would release a large number of free electrons when heated, and that these electrons would flow to and create a "high electron pressure" at the surface of the cathode. Caldwell further believed that this effect, in combination with a large diameter cathode, would increase the output voltage of the thermionic converter disclosed in the '879 patent.

19. Expert testimony at trial establishes the following with regard to the thermionic converter disclosed by the '879 patent:

(a) It would not generate commercially useful electric current and would not produce electric power efficiently or economically.

(b) The size disclosed for a commercially useful device of 5 or more feet in diameter, 10 to 20 feet tall, with electrode spacing of 0.020 inches or less, would not be practical.

(c) Filling the interior of the cathode with inert gas and wires coated with an electron-emitting oxide would not improve the efficiency of the converter by producing additional free electrons that would flow to the anode. The wires and the cathode would be at the same potential, and any electrons emitted from the wires would remain within the cathode. Furthermore, the wires would hamper operation by thermally insulating the exterior surface of the cathode from the heat source.

(d) Increasing the size of the device would not increase the voltage, but rather would increase the current.

(e) The high vacuum between cathode and anode would not, as stated in the patent specification, prevent injury to the electron-emitting coating covering the cathode, but rather would increase the likelihood of injury to the cathode by vaporization of cathode material.

PATENT OFFICE PROSECUTION HISTORY

20. The file history of the original '112 patent can be briefly summarized as follows: The application for the '112 patent, as originally filed, had seven claims. The claims defined the invention in terms of an "electron tube designed to convert heat directly into electricity." All claims were rejected by the patent examiner on May 7, 1954, because they were "drawn to apparatus which is apparently inoperative to carry out the objects of the invention." The only prior art reference cited by the patent examiner was U.S. Patent 2,510,397 to C. W. Hansell, dated June 6, 1950 (hereafter the "Hansell" patent). However, the claims were not rejected over Hansell. In response to the rejection for inoperativeness, a demonstration was performed for the examiner on October 19, 1954,

to illustrate the operability of the Caldwell device. The apparatus demonstrated, however, was not one disclosed in the '112 patent, but rather consisted of a commercially-available 35Z5 high vacuum, indirectly heated, rectifier tube with only a voltmeter connected in the plate-to-cathode circuit. The cathode was heated to dull red heat by passing an alternating current through the heater filament. At the dull red temperature, the cathode thermionically emitted electrons and the voltmeter registered a voltage. The cathode-to-plate spacing in regularly-manufactured 35Z5 vacuum tubes is approximately 0.015 inches.

Despite the above-described demonstration, the examiner, on November 2, 1955, again rejected all seven claims, stating that:

> The claims are rejected as being drawn to a device having little or no utility.
>
> Obviously, the disclosed apparatus is designed to utilize the very well-known phenomena that when a cathode in an electron tube is heated there will be a drift of electrons to the anode of the tube. This drift is composed of a tiny fraction of the available electrons which form a cloud around the cathode (i.e. space charge.)
>
> This phenomena was quite aptly demonstrated by applicants counsel [*sic*] in an interview with the examiner on October 19, 1954. In order for the device to produce any appreciable amount of current it has to be built of huge dimensions. It would require enormous quantity of heat energy [*sic*] to get the cathode up to and maintain it at a suitable operating temperature. Only an extremely slight amount of power would be available and the efficiency therefor would be extremely poor, as efficiency is the ratio of output to input. This, of course, leads to high operating cost. These features are in direct opposition to the stated object, "will act efficiently and economically to produce useable power". [*sic*] * * *
>
> * * * * *
>
> It is obvious to any engineer acquainted with the phenomena involved herein that if the emitter surface is made large enough and the emitter made hot enough, a detectable amount of current might be obtained. No invention would be required to build such a device unless an unexpected amount of power was obtained therefrom. Applicant's device has not been shown to produce any measurable amount of power. * * *

In response to this rejection, the application was amended on April 19 and May 2, 1956, by canceling two claims and adding the further object, quoted in finding 16, of utilizing the device with large sources of waste heat. The examiner then allowed the five remaining claims on May 18, 1956, and the '112 patent issued.

21. The file history of the '879 patent can be briefly summarized as follows: The reissue application for the '879 patent was filed by Mary F. Caldwell and James J. Shanley, plaintiffs herein. The application was identical to the '112 patent, but included 11 additional claims. A principal difference between the new claims and the old is that the new claims defined the invention as "a device for converting heat directly into electricity" rather than an "electron tube designed to convert heat directly into electricity." On October 14, 1958, the patent examiner rejected nine of the new claims as being "fully met" by the Hansell patent; rejected one of the nine claims because it recited "means for withdrawing heat" from the collector and such means were not disclosed; and allowed two claims. In response, applicants filed an amendment dated April 14, 1959, adding seven new claims. The examiner, on May 21, 1959, rejected all 23 claims (five claims from the original '112 patent, 11 claims originally submitted with the reissue application, and seven claims added by amendment to the reissue application), as "fully met" by U.S. Patent 2,437,576, issued to Q. J. Wick, on March 9, 1948 (hereafter the "Wick" patent). By amendment dated November 23, 1959, applicants submitted two new claims and made arguments to distinguish all of the pending claims from the Wick patent. By Patent Office action dated March 28, 1960, all 25 claims were allowed and became the present claims of the '879 patent.

PRIOR ART

22. Defendant put into evidence, among others, the following prior art references in addition to the Hansell and Wick patents:

(a) U.S. Patent 307,031, issued in 1884 to Thomas A. Edison;

(b) U.S. Patent 1,128,229, issued in 1915 to D. F. Comstock;

(c) Schlichter, *The Spontaneous Electron Emission of Incandescent Metals and the Thermionic Cell*, 47 ANNALEN DER PHYSIK 573 (1915);

(d) U.S. Patent 1,653,544, issued in 1922 to H.A. Brown;

(e) Langmuir, *The Effect of Space Charge and Initial Velocities on the Potential Distribution and Thermionic Current Between Plane Electrodes*, 21 PHYSICAL REVIEW 419 (1923);

(f) Champeix, *Considerations on the Transformations of Heat Into Electric Energy in Thermionic Phenomena*, 31 LE VIDE 936 (1951).

None of the above references (a) through (f) was considered by the Patent Office during prosecution of the '879 and '112 patents.

23. The Edison patent (finding 22(a)) discloses a device consisting of a conventional incandescent lamp having its filament connected between the positive and negative terminals of a voltage source; and a conducting substance, such as a platinum plate, placed within the incandescent bulb at a short distance from the filament and connected to the positive terminal of the filament voltage source through a galvanometer. Edison found that when the lamp was operated, a current flowed between the filament and the conducting substance through the vacuum separating the two, and then through the externally connected galvanometer. Furthermore, Edison discovered that this current was proportional to the incandescence or candle power of the lamp. This phenomenon is commonly referred to as the "Edison effect" and demonstrates the principle of thermionic emission.

24. The Comstock patent (finding 22(b)) discloses a device for generating electricity by thermionic emission. Comstock recognized that if a metal emitter is heated to incandescence, electrons would be emitted that could be collected by a cooler metal collector. He taught that the efficiency of this process, being governed by the principles of thermodynamics, could be optimized by maintaining the collector as cool as possible while heating the emitter to "red or white heat." His device consists of an evacuated cylindrical chamber bent at right angles with a collector plate at one end and an emitter plate at the other end.

A coil is wound helically around the vacuum chamber. In operation, the emitter, which is made of or coated with an electron-emissive material, is heated to incandescence by a gas flame, coal fire or other heating means, and emits electrons. An externally-applied electrical current is passed through the helical coil which generates a magnetic field that guides the electrons through the arcuate vacuum chamber to the collector. Since the radiant heat emitted by the emitter travels in straight lines, it cannot traverse the right-angle bend in the vacuum chamber and thus does not impinge directly upon and heat the collector. The collector is further cooled by a water jacket. The Comstock patent does not teach that the emitter and collector be closely-spaced, and it is probable that his device would not produce substantial currents.

25. The Schlichter article (finding 22(c)) discusses some properties of thermionic conversion and discloses a vacuum thermionic converter with closely-spaced electrodes. Recognizing that incandescent bodies emit charged particles, he observed that:

> * * * Even without the help of an accelerating field, these particles can be collected at an opposite electrode with lower temperature * * *. The electrons emitted from the metal [electrode] charge the opposite colder electrode negative, while the emitting electrode itself becomes positively charged by means of loosing [*sic*] electrons; this constitutes a potential difference between the two electrodes.
>
> If the hot and cold electrodes are connected by an external conductor, the arrangement can be considered [a] * * * cell which can deliver energy continuously.
>
> This energy originates from the heat source by means of the electron boiling process and is replenished by the heat source which provides the temperature difference between the electrodes at a predetermined level. *In principle, this constitutes a possibility to directly convert heat energy into electrical energy.*

To prove his thesis, he constructed two thermally-heated, vacuum thermionic converters. In the first converter, the region between two coaxial, concentric quartz tubes is evacuated to a pressure of 10^{-3} to 10^{-4} mm. of mercury. A cylindrical platinum collector 54 mm. long and 6 mm. in diameter is affixed to the outer surface of the inner quartz tube, and

a cylindrical platinum emitter 15 mm. long and 12 mm. in diameter is affixed to the inner surface of the outer quartz tube and positioned coaxially about the center of the longer collector. Thus, the spacing between opposing emitter and collector is 3 mm., or 0.117 inches. The emitter is uniformly heated by placing this assembly into the cylindrical opening of an electric oven. External leads are brought out from the emitter and collector to measure the thermionic current flow.

In the second converter, a cylindrical quartz tube having a U-shaped seal at one end is positioned concentrically within another, slightly larger diameter quartz tube also having a U-shaped seal at one end to form a U-shaped cavity between the tubes. This cavity is also evacuated to a pressure between 10^{-3} and 10^{-4} mm. of mercury. A cup-shaped emitter is affixed to the outer surface of the U-shaped portion of the inner tube. A cup-shaped collector of essentially the same area as the emitter is affixed to the inner surface of the U-shaped portion of the outer tube. Thus, the collector and emitter face each other across the cavity, and the emitter is completely surrounded by the collector. The emitter is heated by an electrical heating element placed within the inner quartz tube, and the collector is cooled by water circulating through a cooling coil wrapped around the outer quartz tube. External leads are brought out from the emitter and collector to measure the thermionic current flow. No dimensions are given for the construction, other than that the total heated cathode area was 23 sq. cm. The article states, however, that the vacuum should be high enough so that the mean free path of electrons among residual gas molecules (average distance traveled by an electron before colliding with a gas molecule) is greater than the interelectrode spacing. For a vacuum of 0.01 mm. of mercury, Schlichter suggests an interelectrode spacing of less than 5 mm. (0.195 inches), and it can be assumed that such spacing was used in the second converter. The emitter and collector were both made of platinum in one experimental converter and nickel in another.

While both types of experimental converters disclosed by Schlichter were equipped with pure metal electrodes, Schlichter recognized that a surface layer of adsorbed impurities

exists on nickel electrodes. From experiments performed with nickel electrodes and described in this reference, Schlichter determined that they become coated with a thin layer of nickel oxides. Furthermore, he noted that such an electrode exhibits properties similar to platinum electrodes coated with calcium oxides or barium oxides, one of which is increased electron emission.

Schlichter's experiments for both converters were conducted with the emitters heated to 1000° C., and with a galvanometer and resistance connected in series externally between emitter and collector. He found with both converters that, as the external resistance was increased from zero ohms to 93.4 megohms, the terminal voltage between collector and emitter increased from zero volts to 0.365 volts, and the current decreased from 0.0874 microamps to 0.0039 microamps.

The Schlichter paper concludes by observing that:

> Thermionic cells are feasible. Because of the very high radiation losses, they operate entirely uneconomically. However the radiation losses are the only reason for their impractical application. If radiation losses could be eliminated, they would operate with a significantly high efficiency.

26. The Brown patent (finding 22(d)) discloses a conventional triode electron tube (*i.e.*, a tube with three electrodes—cathode, anode and control grid) having a cathode directly heated to incandescence by a battery and, as a new improvement, a mixture of alkaline metal vapors, such as sodium and potassium. Brown discovered that such a tube provided greater amplification than previous vacuum tubes and produced an anode current with no externally applied anode and control grid voltages. Thus, in this mode of operation, his tube functioned as a gaseous thermionic converter, although the patent discusses the tube as an improved amplifier and not as a source of power.

27. The Langmuir article (finding 22(e)) discusses from a theoretical standpoint the effect of space charge and cathode temperature on thermionic current and voltage, noted in finding 8. Langmuir postulated a mathematical model consisting of opposing parallel, planar cathode and anode with the anode spaced at an infinite distance from the cathode so that there was no current flow to the anode and no potential

gradient near the anode. With this model, he was able to study the space charge uninfluenced by the anode or external voltages. He discovered that, except very close to the cathode, the electron density in the space charge was independent of cathode material, was proportional to cathode temperature, and was inversely proportional to the square of the distance from the cathode. Furthermore, the voltage potential near the cathode increased as the logarithm of the distance from the cathode. Thus, Langmuir mathematically demonstrated that, in the absence of an external anode voltage (which tends to overcome the space charge), the space charge acts as a barrier that inhibits electrons emitted from the cathode from traveling any appreciable distance. Put another way, a negatively-charged electron at the cathode sees a negatively-charged cloud of electrons which tends to repel the electron back toward the cathode, since like charges repel. For an electron to penetrate the cloud of electrons, it must have a sufficiently high energy, *i.e.*, velocity, as it leaves the surface of the cathode; otherwise, it will be trapped within the space charge cloud or repelled back to the cathode.

28. The Champeix article (finding 22(f)) discusses the operation of vacuum thermionic converters in relation to the laws of thermodynamics. He observes that, by Carnot's principle, to convert heat energy into electrical energy requires a cold source within the system. He experimentally determined that in a thermionic converter, the cold source is simply the anode. Consequently, heating the anode reduces the thermionic current; and when the anode reaches the same temperature as the cathode, thermionic current ceases. Champeix also recognized that space charge adversely influences the flow of thermionic current, and therefore postulated a thermionic converter model with very closely-spaced electrodes to eliminate the effect of space charge phenomena, although the article does not teach any specific interelectrode spacings. With this assumption, he calculated that for a vacuum thermionic converter having an oxide cathode operated at 1000° K. (727° C.), the theoretical efficiency was only 1.5 percent. He suggests, however, that since some cathodes can be operated up to 2500° K. (2227° C.), and since the anode can be cooled at will, a theoretical yield of 50–60 percent is feasible.

29. The Wick patent, which was cited by the Patent Office during prosecution of the '879 patent, discloses a triode vacuum tube having a flame-heated cathode. Although this device does not operate as a thermionic converter because it uses an externally-applied anode voltage, its structure is of interest. A Bunsen burner is positioned at the center of the tube through an open space at the bottom of the tube to supply heat. Surrounding it is a hollow, generally cylindrically-shaped cathode having radial fins extending the length of the cathode. A cylindrical wire mesh grid surrounds the cathode, and a cylindrical metal anode surrounds the control grid. Annular insulating rings at both ends of the anode cylinder maintain it concentric with the cathode. A metal cover fits over the top of the tube, and an annular insulator ring, through which passes the Bunsen burner, fits around the bottom of the tube. The region between cover and cathode is evacuated.

30. The Hansell patent, which was cited during prosecution of the '879 patent, discloses a heat-to-electrical energy converter consisting of two parallel, flat metal sheets separated by a gas-filled cavity. For proper operation of the Hansell device, the work function of one sheet must be greater than the ionizing potential of the gas, which, in turn, must be greater than the work function of the second sheet. The work function of a material is the amount of energy necessary to remove an electron from the surface of the material. (See finding 6.) The ionizing potential is the amount of energy necessary to remove an electron from a gas molecule.

In the Hansell device, the sheet having the higher work function is heated by an external heat source to a temperature *below* substantial thermionic electron emission. The gas is at a pressure such that only a single layer of gas molecules condenses on the surface of each sheet. The heat applied to the sheet of high work function causes evaporation of the gas molecules from its surface. Since the ionizing potential of the gas is less than the work function of this sheet, *i.e.*, it takes less energy to remove an electron from the gas than from the sheet, the evaporating gas molecules give up electrons to the sheet and evaporate as positively-charged ions. Some of the positively-charged ions drift over to and condense on the surface of the second sheet. This sheet is also

hot, due to thermal radiation from the first sheet, and evaporation again occurs. However, since the ionizing potential of the gas is greater than the work function of the second sheet, the sheet gives up electrons to the positive ions which then evaporate as neutral, uncharged gas molecules. Some of these molecules eventually recondense on the first sheet and the cycle begins anew. Thus, by a gas transport mechanism, electrons are transferred from the low work function sheet to the high work function sheet. Accordingly, the high work function sheet acquires an excess of electrons with respect to the low work function sheet, and an electron current will flow from the former, through an external circuit, to the latter.

Hansell specifies that the sheets should be "at as close a spacing as is practical without contact and without causing a short circuit, electrically." He also discloses a list of usable materials, along with either their ionizing potentials or work functions, as appropriate; and he refers to experiments conducted with cesium as the vapor material and platinum as the material for the high work function sheet.

31. With regard to other pertinent prior art (not listed in finding 22), the parties have agreed by stipulation filed November 29, 1971, as follows:

* * * * *

15. (3) Electron tube technology needed for thermionic converter construction and operation was well established in the electron tube art prior to 1930. For example, Langmuir U.S. Patent 1,723,869 (1929) teaches the use of cesium vapor ionized by heat to overcome electron space charge in electron tubes. Kingdon and Langmuir U.S. Patent 1,648,312 (1927) teaches the use of adsorbed cesium vapor as a coating on electron tube electrodes to increase their electron emission characteristics. * * *

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THE ACCUSED DEVICES

32. With regard to Government expenditures for and use of thermionic converters, the parties have agreed by stipulations filed November 29, 1971, as follows:

STIPULATION

1. Total Government expenditures for thermionic converter research and development in the time period of

1958 to the present has exceeded fifty million dollars ($50,000,000).

* * * * *

STIPULATION III

* * * * *

18. All thermionic converters made for and delivered to the United States to date were made for the United States and used by the United States for experimental purposes to develop thermionic converters which could be used in practical applications. Thermionic converters delivered to the United States were used without any intent by the United States to derive profit or practical advantages from the delivered converters but solely to experiment with such converters and perform research on them for the purpose of developing converters useful in various applications where electric power is needed.

* * * * *

33. The parties have agreed by stipulation filed November 29, 1971, that "a majority of the defendant's accused devices are of the 'cesium' thermionic converter type, which are being developed for use with atomic energy, fossil fuel or solar radiation heat sources, and in which electron bombardment heating may be used for testing. Heat pipes are used in conjunction with some of the accused devices for either conveying heat to the emitters or withdrawing heat from the collectors, or both. The defendant's accused devices are generally of either cylindrical or planar configuration." More specifically, the Government agencies involved in thermionic converter research and development, and representative thermionic converters they have investigated, are described below in findings 34 to 38.

34. National Aeronautics and Space Administration (NASA)—The NASA thermionic converter program began in 1961 as a long-range effort to determine the feasibility of and to provide data for thermionic converters as an advanced power system for space use. NASA initially experimented with high-vacuum thermionic converters but then abandoned this effort and began experimenting with cesium converters.

The evidence shows that NASA has been supplied with thermionic converters for its research program by the following contractors: Thermo Electron Engineering Corporation (TEECO); Gulf General Atomics Corporation; Radio Corporation of America (RCA); and General Electric Company

(GE). For example, in 1962, RCA developed a cesium thermionic converter, Developmental-Type A–1270, for NASA under Contract No. NAS–7–100 with the Jet Propulsion Laboratory of the California Institute of Technology (JPL). This converter was designed to be heated either by concentrated solar energy or electron bombardment. The collector was a molybdenum cylindrical rod. The emitter was a tantalum cylindrical tube, closed at one end, which fit over and was slightly spaced from the collector, although there is no evidence of the electrode separation distance. The emitter was electrically insulated from the collector by an annular ceramic insulator. The interelectrode region was connected to a cesium reservoir. Excess heat was removed by radiation from the collector. Typical ratings for a single converter were 30 watts output power, and 6 percent conversion efficiency, at 1725° C. emitter temperature and 700° C. collector temperature.

Under the same contract, JPL investigated for NASA more than 135 cesium thermionic converters having the following characteristics:

(1) The majority of the converters had planar, confronting electrodes having an interelectrode spacing of approximately 0.0005 inches, although some converters had interelectrode spacings of 0.005 and 0.020 inches, and some converters had cylindrical electrodes.

(2) The converters operated at emitter temperatures between 1627° and 1727° C. and collector temperatures between 527° and 827° C.

(3) Emitters were made of rhenium; collectors were made either of molybdenum, rhenium, palladium, or neobium; insulators for insulating the electrodes were made of alumina ceramic.

(4) The measured efficiency of the tested converters was between 10 and 12 percent.

The evidence also establishes that most, if not all, NASA cesium thermionic converters had interelectrode spacings of 0.020 inches or less.

35. Army—The Army began investigating thermionic converters in 1958. Their first converter consisted of a simple diode vacuum tube with a movable electrode so that the spacing between emitter and collector could be varied. The emitter

was made of tungsten and the collector of nickel. The cathode was indirectly heated by an electric filament. There was no cesium in the tube and no coating on the tungsten. The spacing between emitter and collector could be varied between "almost touching" to approximately one-quarter inch. Investigation of this device was terminated because its efficiency was too low for practical utility.

In the early 1960's, the Army contracted with Marquart Corporation to investigate new methods of injecting positive ions into thermionic converters. For example, lithium ions were generated to determine whether they could neutralize the space charge between electrodes. The results of this program showed that the efficiency of ion generation was very low, and, consequently, the program was terminated.

In 1961, the Army contracted with TEECO to develop a flame-heated thermionic generator capable of operating on fuels available in the field, such as motor-vehicle fuel. As of the time of trial, this effort had reached only 80 percent of the desired index goal, based on output power, weight, efficiency, emitter temperature, and lifetime of the converter. Furthermore, the contractor has indicated that it would be impossible to achieve 100 percent of the desired goal.

The evidence also establishes that prior to 1965, the Army, under Task No. 1C6–22001–A–053–03, experimented with cesium thermionic converters having the following characteristics: interelectrode spacing of 0.013 inches; emitter temperature between 1388–1390° C.; collector temperature between 482–552° C.; planar-shaped molybdenum emitter; and planar-shaped nickel collector.

36. Navy—The Navy thermionic converter program began in 1960. It was directed primarily toward basic research in an attempt to gain an understanding of the thermionic process, rather than toward producing a practical device. Nevertheless, the Navy sponsored the development of two cesium thermionic converters, Developmental-Type Nos. A–1197A and A–1272, under Contract No. NObs 84823 with RCA.

The A–1197A converter was designed to be heated by nuclear energy. The emitter was a hollow, cylindrical tube made of molybdenum and the collector was a hollow, cylindrical tube made of nickel which fit over the emitter. The hollow

center of the emitter was a nuclear fuel chamber which contained the nuclear emitter-heating material. The collector was spaced from the emitter by annular ceramic insulators but there is no evidence of the separation distance between them. Excess heat was removed from the converter by heat sinks in contact with the emitter and collector contact areas. Typical ratings for this device were 206 watts output power and 13 percent conversion efficiency at 1545° C. emitter temperature and 588° C. collector temperature.

The A–1272 converter was also designed to be heated by nuclear fission. The emitter and collector were essentially of the same hollow, cylindrical design as in the A–1197A converter. A cylindrical cooling jacket surrounded the collector to cool it. The electrodes were spaced apart by ceramic insulators. There is no evidence of collector or emitter materials or the separation distance between electrodes. Typical ratings for this device were 400 watts output power and 16.7 percent conversion efficiency at 1610° C. emitter temperature and 740° C. collector temperature.

In addition, the parties have agreed, by stipulation dated November 29, 1971, as follows:

* * * * *

14. A more specific insight into the interrelationship of the various key factors of thermionic converter construction and operation can be found in * * * Defense Documentation Center report AD626593, a 15 December 1965 report of Martin-Marietta Corporation under Navy Contract Nonr–3639(00):

* * * * *

(3) The effect of the emitter collector spacing of some tubes is shown by Figure IV–20, of the Martin-Marietta report * * *. This chart illustrates the effect of an emitter-collector gap for a cesium diode of 0.004 inches, 0.008 inches, 0.015 inches and 0.025 inches, for three different collector materials. The power output radically declines from over seven watts to less than three watts as spacing is increased from 0.004 inches to 0.025 inches. * * *

37. Air Force—The Air Force thermionic converter research program began prior to 1960 under contracts with GE and TRW Corporation for the development of solar-heated vacuum thermionic converters. GE was to supply a 500-watt output, 5 percent efficient converter having interelectrode

spacing of approximately 0.00025 inches and 100-hour lifetime. The program was terminated, however, because the converter developed by GE was only capable of producing 100-watts output at a maximum efficiency of 2 percent and operated without failure only for a few hours.

TRW was to supply a 100-watt output, closely-spaced vacuum thermionic converter, but they concluded shortly after the program began that they could not build a suitable device. Consequently, they recommended switching their efforts to cesium thermionic converters and subsequently built a small cubicle cavity, solar thermionic converter having an efficiency of 3–4 percent.

In 1962, the Air Force abandoned all work on vacuum thermionic converters. Subsequently, contracts were made with TEECO and RCA for cesium thermionic converters. By 1965, TEECO had supplied converters capable of operating for several thousand hours at emitter temperatures of 1700° C. and 10-percent efficiency. Under Contract No. AF33(657)–8005, RCA developed two cesium thermionic converters for the Air Force, Developmental-Type Nos. A–1198B and A–1274.

The A–1198B converter was designed to be heated by a liquid metal loop. The emitter was a hollow, cylindrical tube made of molybdenum, and the collector was a hollow, cylindrical tube made of nickel. The tubing for the liquid metal heat source ran through the interior of the emitter cylinder. The collector was spaced from the emitter by annular ceramic insulators, but there is no evidence of separation distance between electrodes. Excess heat was removed from the collector by radiating fins. Typical ratings for this converter were 43.5 watts output power and 6.7-percent efficiency, at 1200° C. emitter temperature and 550° C. collector temperature.

The A–1274 converter consisted of three internally series-connected cesium converters and was also designed to be heated by a liquid metal loop. The construction of each converter was essentially the same as in the A–1198B converter, except that a single heating tube passed through all three converters. Typical ratings were 77 watts output power and a 7-percent conversion efficiency, at 1227° C. emitter temperature and 650° C. collector temperature.

The parties have also agreed by stipulation dated November 29, 1971, as follows:

* * * * *

14. A more specific insight into the interrelationship of the various key factors of thermionic converter construction and operation can be found in Defense Documentation Center Document AD 464636, an April 1965 report of Radio Corporation of America under Air Force Contract AF 33 (615)-1547 * * *.

(1) Effects of various emitter operating temperatures are found in Figures 31–36, pp. 64–69, of the RCA report * * *. The effect is an increase in maximum output from 90 watts at an emitter temperature of 1200°C to 420 watts at an emitter temperature of 1450°C for the RCA A–1274A three-converter module from which the data was taken.

(2) The effect of collector temperature is illustrated in Figure 70, at page 116 of the RCA report (Attachment C). Note that at 1350°C emitter temperature over 2 watts is obtained with a collector temperature of 750°C, compared with only approximately 0.5 watts for a collector temperature of 900°C. Similarly, for an emitter temperature of 1500°C, the respective watts output for various collector temperatures is: 750°C–6.5 watts; 900°C–4.5 watts; 1000°C–1.5 watts; 1200°C–0 watts. This clearly illustrates the need for maintaining the collector cool relative to the temperature of the cathode and to include means for removing heat from the collector.

* * * * *

(4) The RCA report shows in Figures 31–36, referred to above, cesium reservoir temperatures in the range 262°C–291°C. This corresponds to a pressure of approximately 0.5 millimeters of mercury at 260°C to 1.8 millimeters of mercury at 300°C.

38. Atomic Energy Commission (AEC)—The AEC program in thermionic converter research began in the period 1957–58 and, from the outset, was concerned primarily with cesium converters. By 1959, the AEC had developed a nuclear-heated thermionic converter consisting of an emitter made of a pin of uranium carbide-zirconium carbide surrounded by a cylindrical collector made of stainless steel. Neutron flux from a nuclear reactor caused the uranium pin to fission, raising its temperature to about 1900° C. This de-

vice had a maximum efficiency of 10 percent. By 1969, the AEC had investigated cesium converters having an emitter temperature of 1637° C. and an emitter spacing of 1 mm. (0.039 inches). The evidence shows that the AEC has contracted for the development of thermionic converters and supporting technology with GE, the GA Division of General Dynamics Corporation, TEECO, and RCA.

Conclusion of Law

Upon the foregoing findings of fact and opinion, which are made a part of the judgment herein, the court concludes as a matter of law that plaintiffs are not entitled to recover, and plaintiffs' petition is dismissed.

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